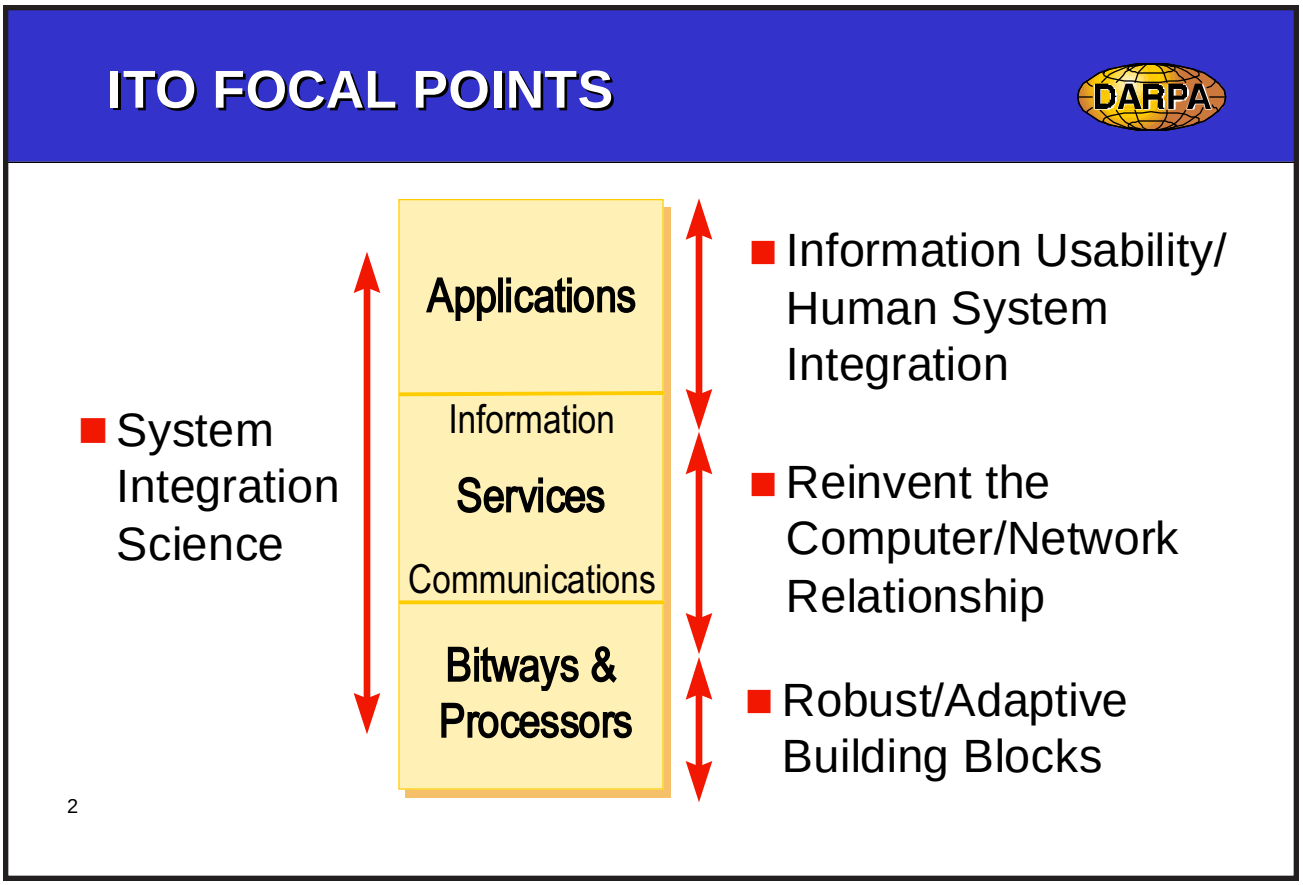
Dr. Tennenhouse is on secondment to DARPA from MIT's Laboratory for Computer Science and Sloan School of Management.

David's research has focused on systems and strategy issues related to distributed computing and communications. He has taught courses on networking, computer systems engineering, computer architecture and information infrastructure.

Dr. Tennenhouse and his students (www.sds.lcs.mit.edu) have been involved in the early development of ATM, Active Networks, Desktop Multimedia, Software Radio & Software-Based Sample Processing.

Additional information concerning DARPA's ITO office can be found at www.ito.darpa.mil.



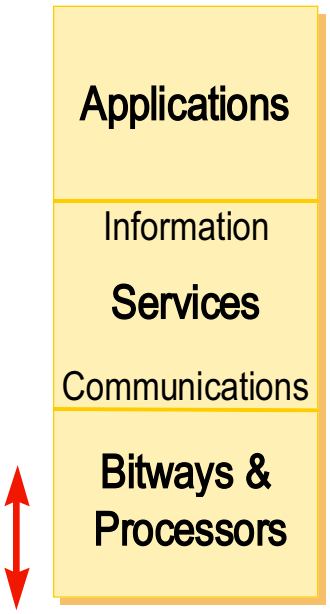
The ITO research program is organized into four areas, as illustrated in the above diagram. Within each of these areas, ITO conducts 3- to 5-year research programs/projects that have specific objectives.

In this afternoon's talk, I will step through each of these areas, using some of the programs presently underway as examples of our work in progress.

Later on in this conference, you will be hearing directly from the program managers responsible for the planning and execution of some of our most recent efforts.

ROBUST/ADAPTIVE BUILDING BLOCKS

- Scalable/Embeddable Computing
- Adaptive Computing Systems
- Broadband Info Technology
- UltraScale Computing



3

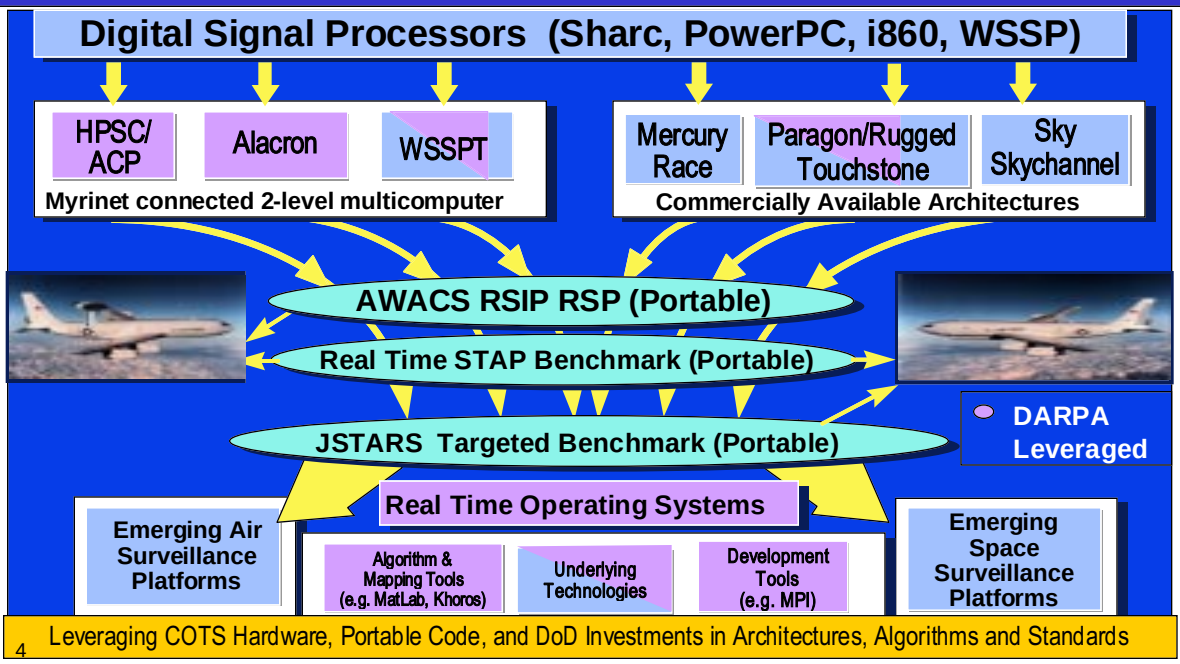
ITO continues to explore new models of computation and communication, together with the substrates through which those models can be realized.

In addition to our traditional emphasis on raw capacity, we are stressing adaptive technologies that can be dynamically tailored to suit changing mission requirements.

Later in this conference, you will be hearing about two very different types of “building block” activities:

- Data Intensive computing, addressing the data “starvation” caused by today’s memory subsystems
- UltraScale, a “seed” project exploring alternative models, such as Quantum and DNA-based computing

EMBEDDABLE SYSTEMS

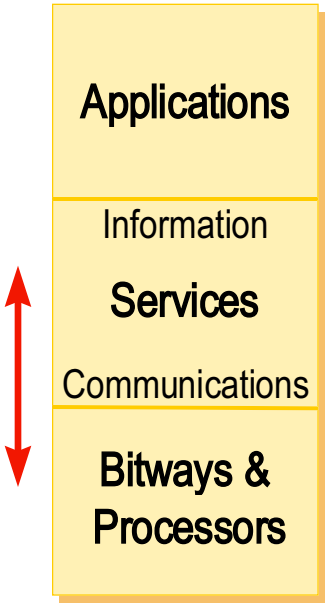


REINVENTING THE COMPUTER/ NETWORK RELATIONSHIP

- Global/Mobile Systems
- Quorum O.S.
- Active Networks
- System Environments

1998 Programs **New!**

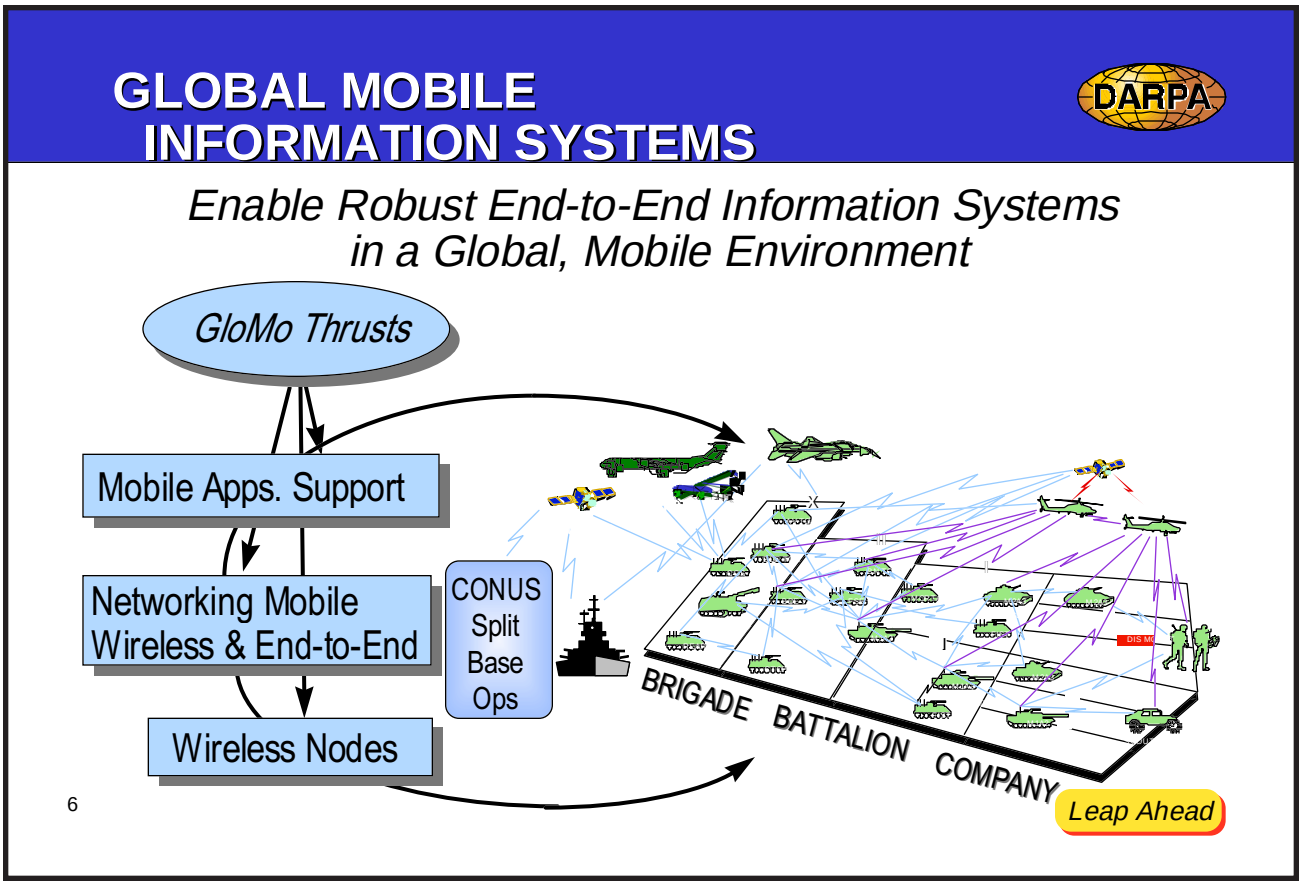
- Next Generation Internet



5

A distinguishing characteristic of ITO has been the upwards spiral we have created through substantial and complementary achievements in

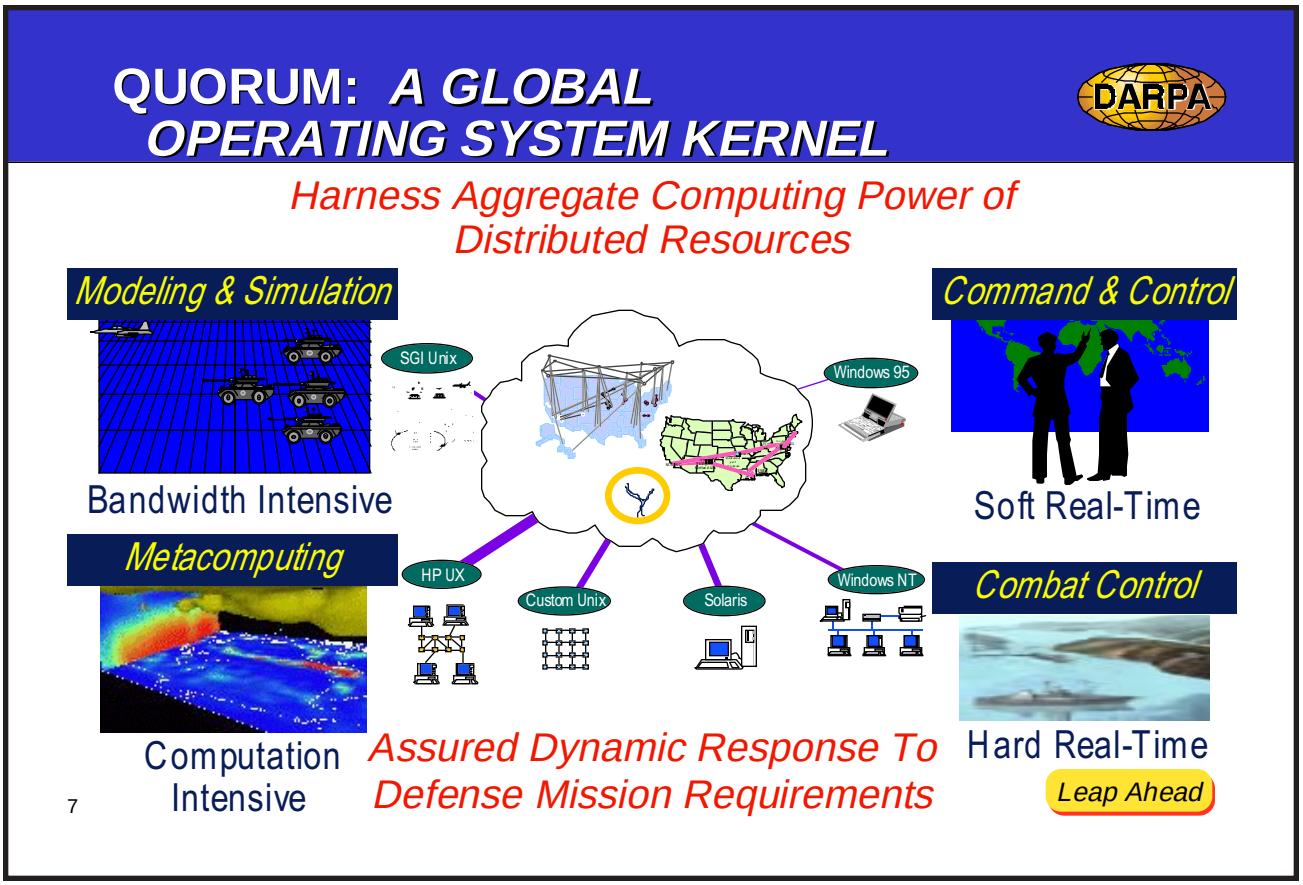
- network-enabled computation capabilities, such as networks of workstations; and
- computation-enabled networking technologies, such as packet switching and active networks.



Technologies under development within our GloMo program will deliver the services of the global Defense Information Infrastructure to the low bandwidth regions near the tip of the spear.

GloMo is exemplary of the ITO cauldron:

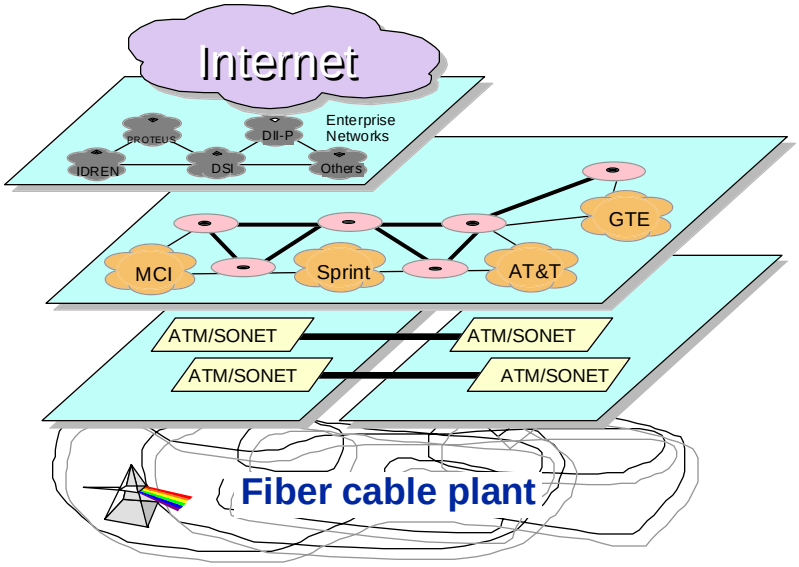
- It is changing the nature of battlefield computation through the development of network-based services, e.g., distributed systems that tolerate disconnection.
- In parallel, GloMo is leveraging computation to enhance network operation through technologies such as software radio and multihop network routing.



As “embedded” and “real-time” systems become networked, there is increased demand for them to support the same services, protocols and development environments that are available on “mainstream” network-based platforms.

At the same time, increased reliance on those “mainstream” systems and their composition to form global command and control environments has engendered concerns regarding assured response and robustness.

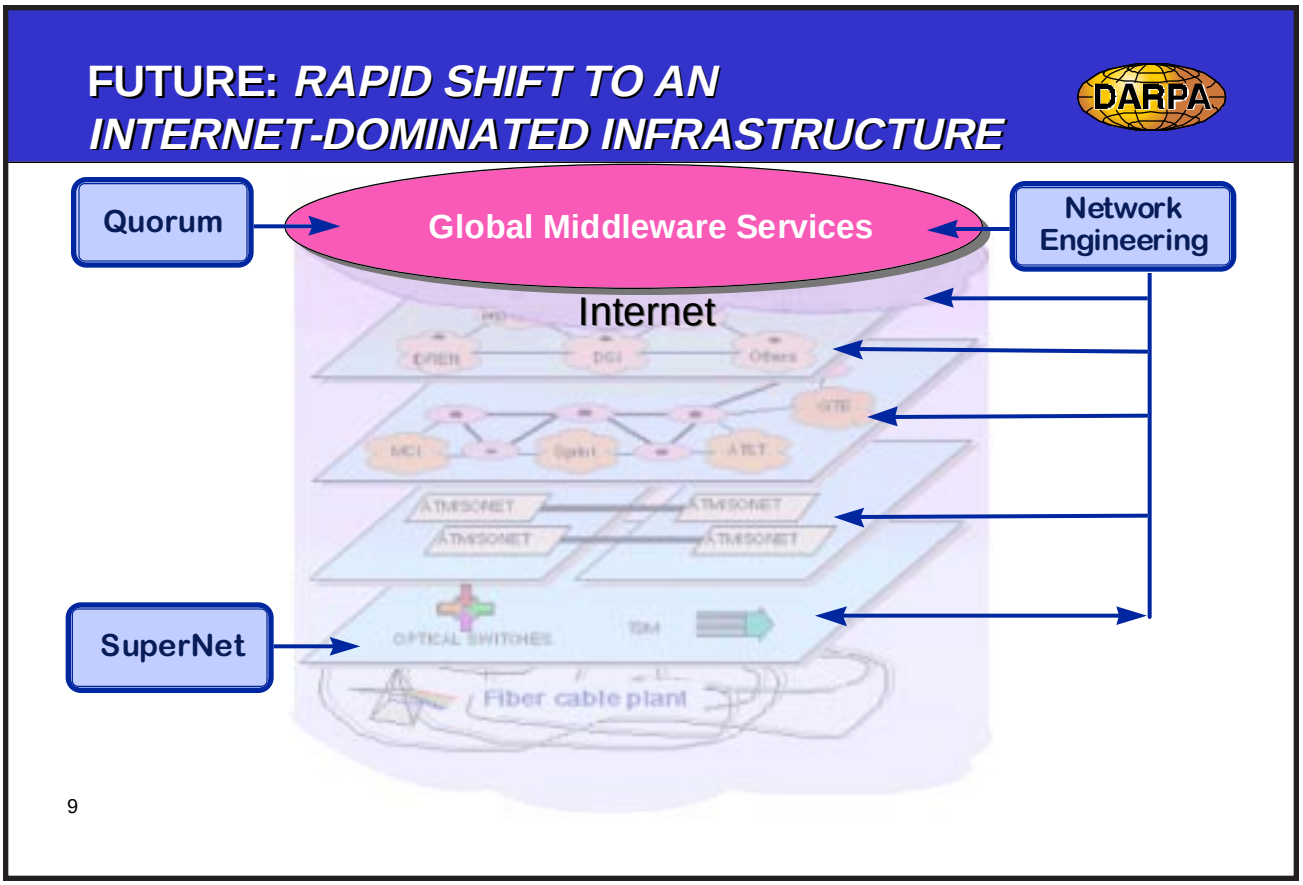
PRESENT: *INTERNET OVERLAYS A VOICE DOMINATED SUBSTRATE*



8

An interesting aspect of the Next Generation Internet Initiative, beyond its technical agenda, is the time window in which it will be executed.

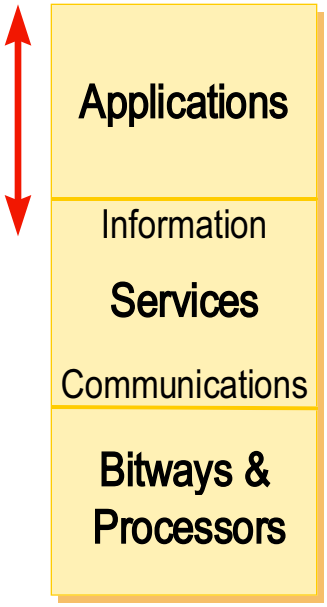
The above slide illustrates the present state of affairs in which the Internet represents a minority, yet growing fraction of the traffic carried over a voice-dominated telecommunications infrastructure.



However, the balance of traffic is shifting so rapidly that soon after the NGI effort is finished, the infrastructure will be dominated by packet-based traffic.

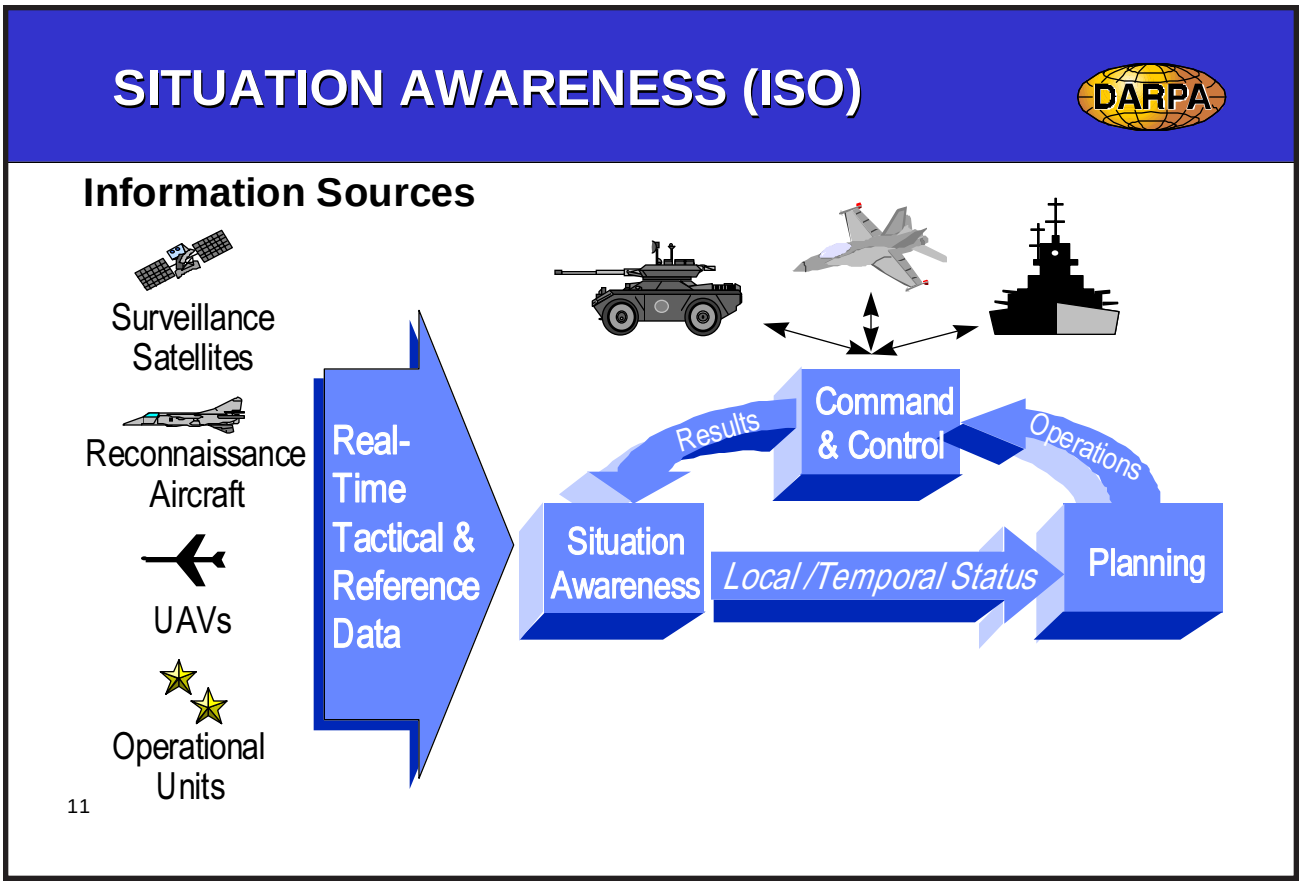
INFORMATION USABILITY

- Information Management
- Collaboration & Visualization
- Human Language Systems

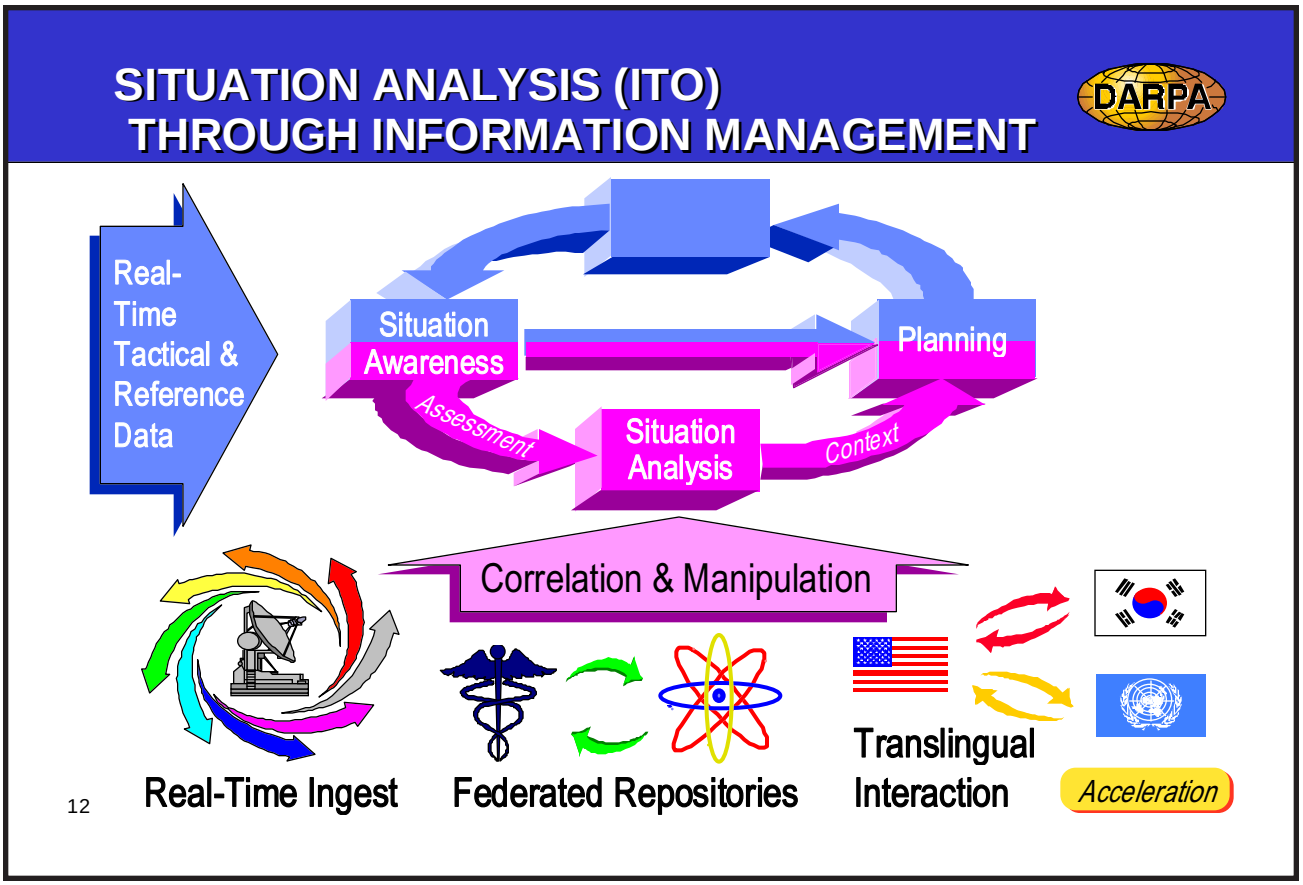


10

With the increase in information and communication capabilities, comes the need for tools that allow us to organize and interact with our information asset.



This slide illustrates the Situation Awareness activities, underway within ISO, one of our sister offices at DARPA. It illustrates the huge intake of battlefield-related information and its processing through the Command & Control loop.



Within ITO, we are undertaking a complementary effort to develop a situation analysis capability that leverages worldwide information assets and organizes them in a way that facilitates correlation and manipulation across a range of media, languages and disciplines.

INTELLIGENT COLLABORATION & VISUALIZATION

DARPA

Collaborate on the Move Across Time and Space

Semantic-Based Collaboration Tools

- Situation Gister
- Semantic Indexer
- Collaborator Search Engine

Team-Based Visualization Software

- Role-Based Rendering
- Shared Animation
- Immersive Spaces

Scalable Reliable Multicast & Semantic Multicast

- Transcoders
- Active Object Coordinator
- Local and Global Session Managers
- Continuous Media Tools

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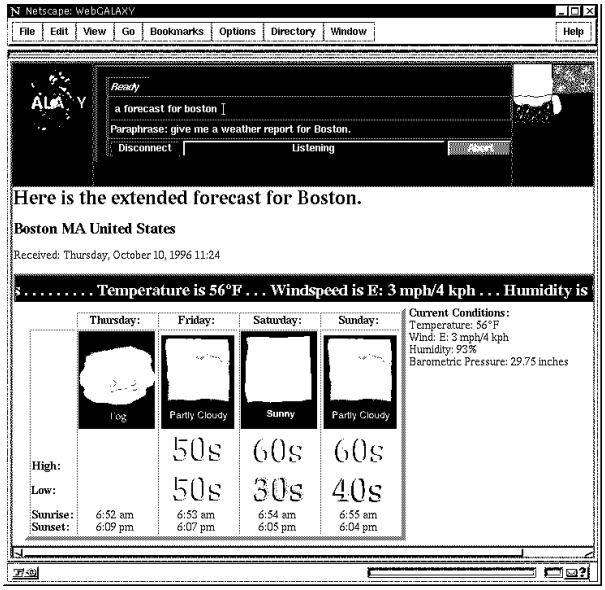
Our collaboration and visualization activities will support the dynamic synthesis of human and information assets into symbiotic teams that can interact across time and space.

HUMAN LANGUAGE SYSTEMS

DARPA

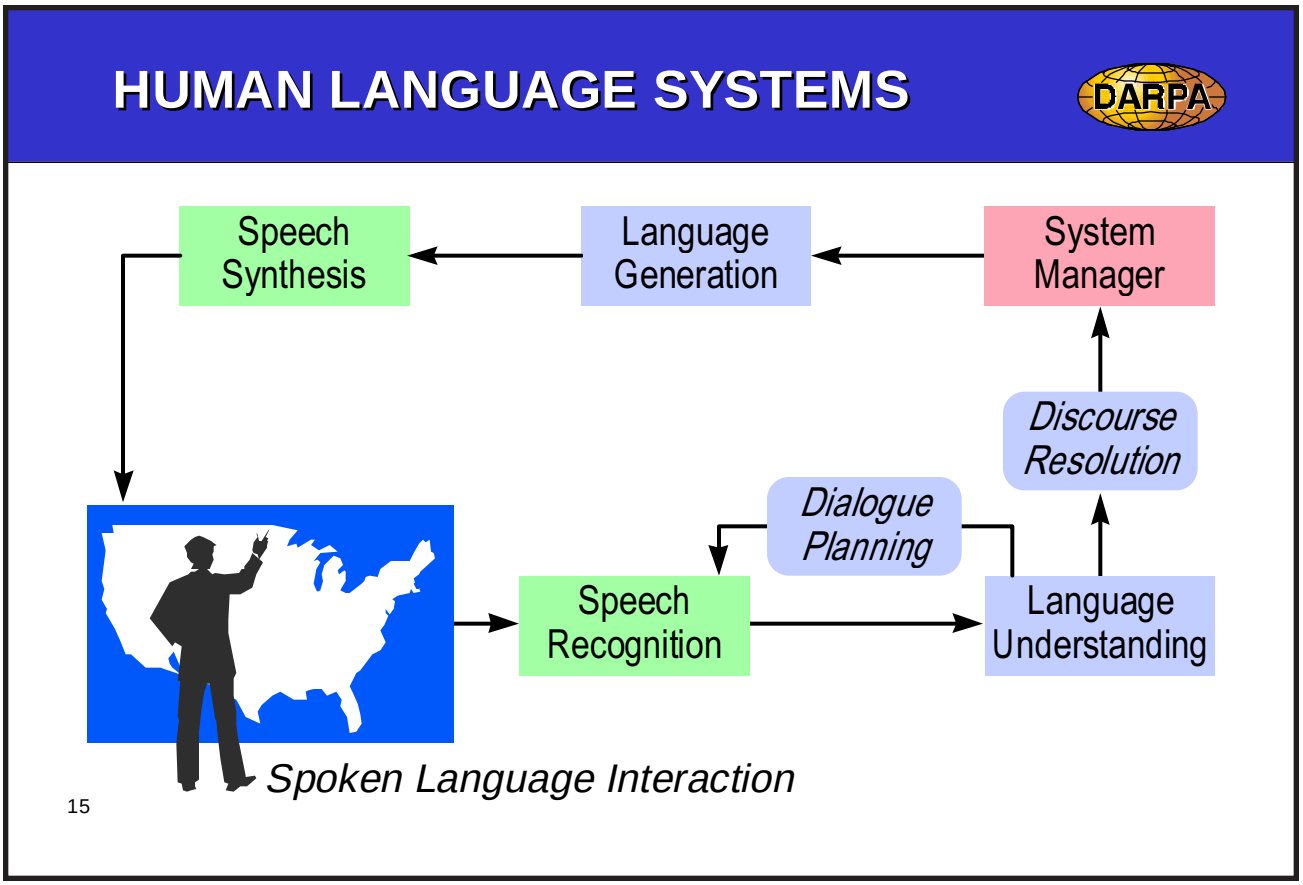
GALAXY

Enable Computers to Hear and Read – and Understand What They Hear and Read



Leap Ahead

Sustained investment in spoken language technologies has resulted in mixed-media systems that are web-based, operate in real-time and are speaker-independent.



This diagram illustrates the "dialogue-based" architecture used to integrate speech-related technologies into systems that support a range of domain-specific applications.

The outer feedback loop allows the computer and its user to interactively close gaps in their understanding of each other. Note the "inner" feedback loop in which two of the key software components engage in similar interactions.

DARPA-sponsored dialogue technology has been successfully demonstrated in application domains, such as

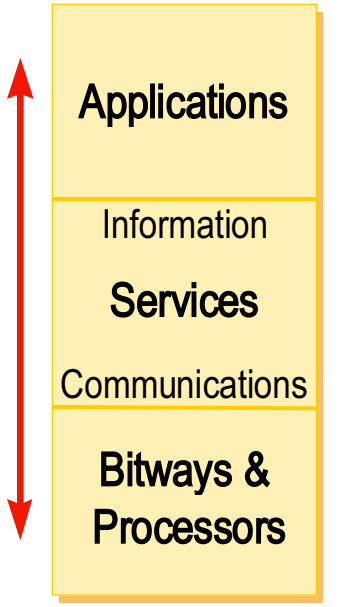
- Travel planning
- Product information access
- Radio/Television News ingestion
- Multi-lingual interaction

We have come a long way with this technology.

I believe that it is now ripe to be “harvested”– and that doing so may have substantial implications for how we think about many other aspects of information systems.

So, the question I have for those of you in the audience is “where do we speak next?”

SYSTEM INTEGRATION SCIENCE



Model, Design & Compose Large-Scale Systems

- Information Survivability
- Evolutionary Design of Complex Software

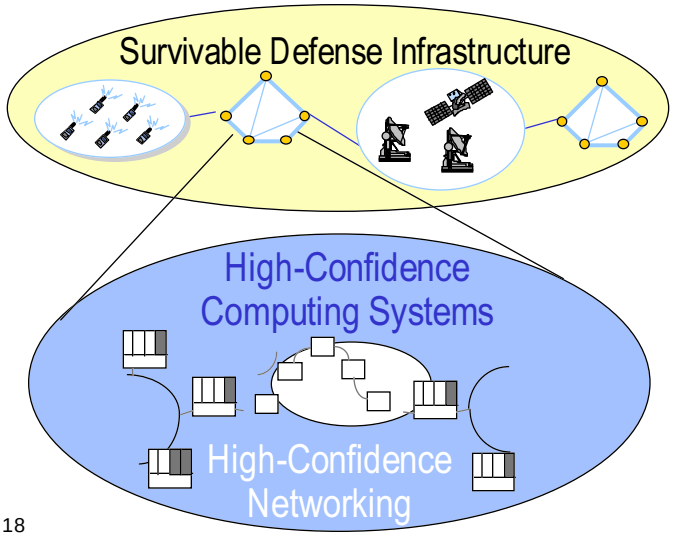
17

As networked systems grow in their sophistication, so does our need to harden them against attack and learn how to protect our software investments in the face of the very innovation we are striving for.

INFORMATION SURVIVABILITY

DARPA

Detect, Isolate, Repel, and Survive Concerted Information Attacks



Environment:

- Brittle COTS Products/ Infrastructure
- Increased Risk From Dependence on This Technology
- Little or No Outside Investment to Address Denial-of-Service Attacks

Leap Ahead

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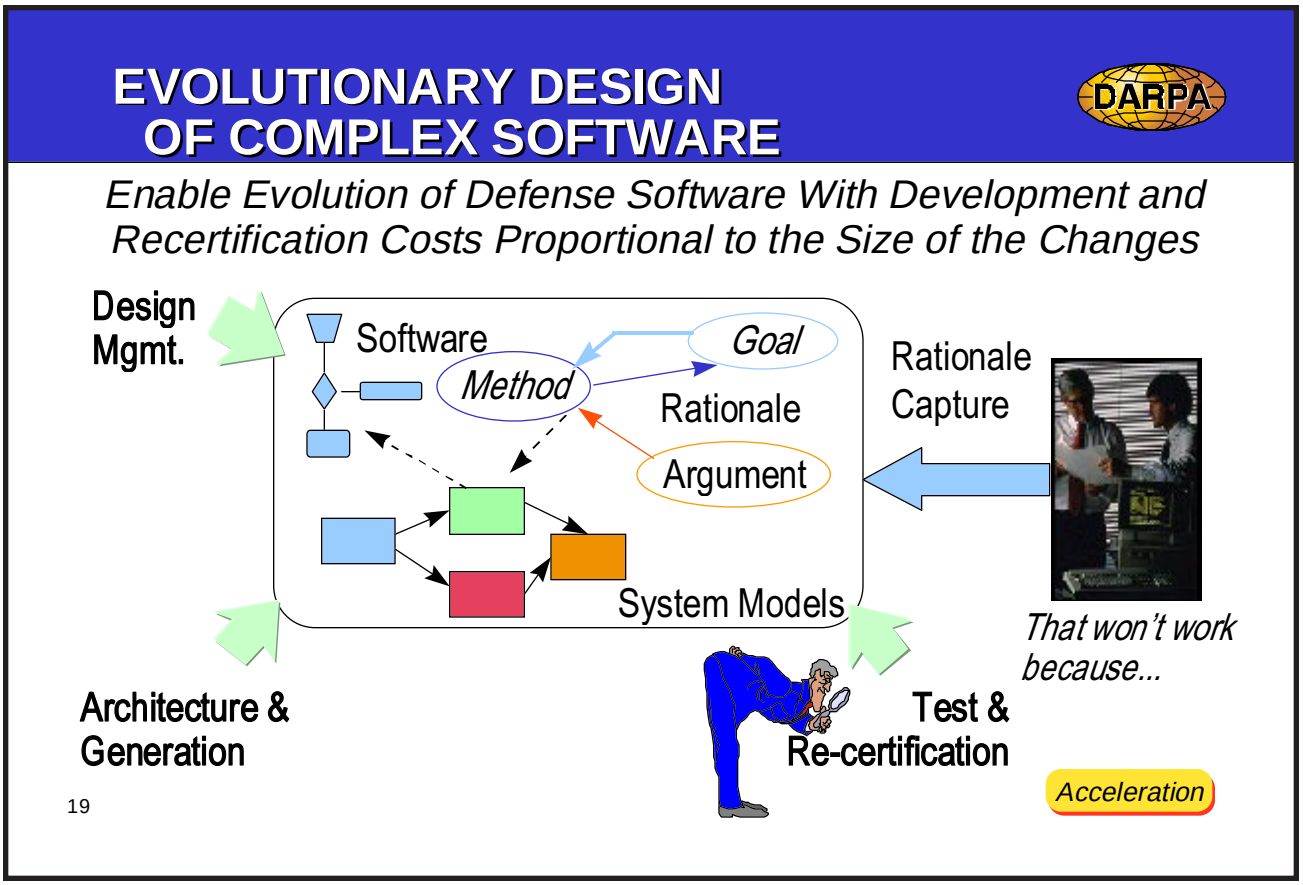
The ISO office is developing IS extensions to its reference architecture and the two offices are cooperating to populate the ISO architecture with newly developed technologies.

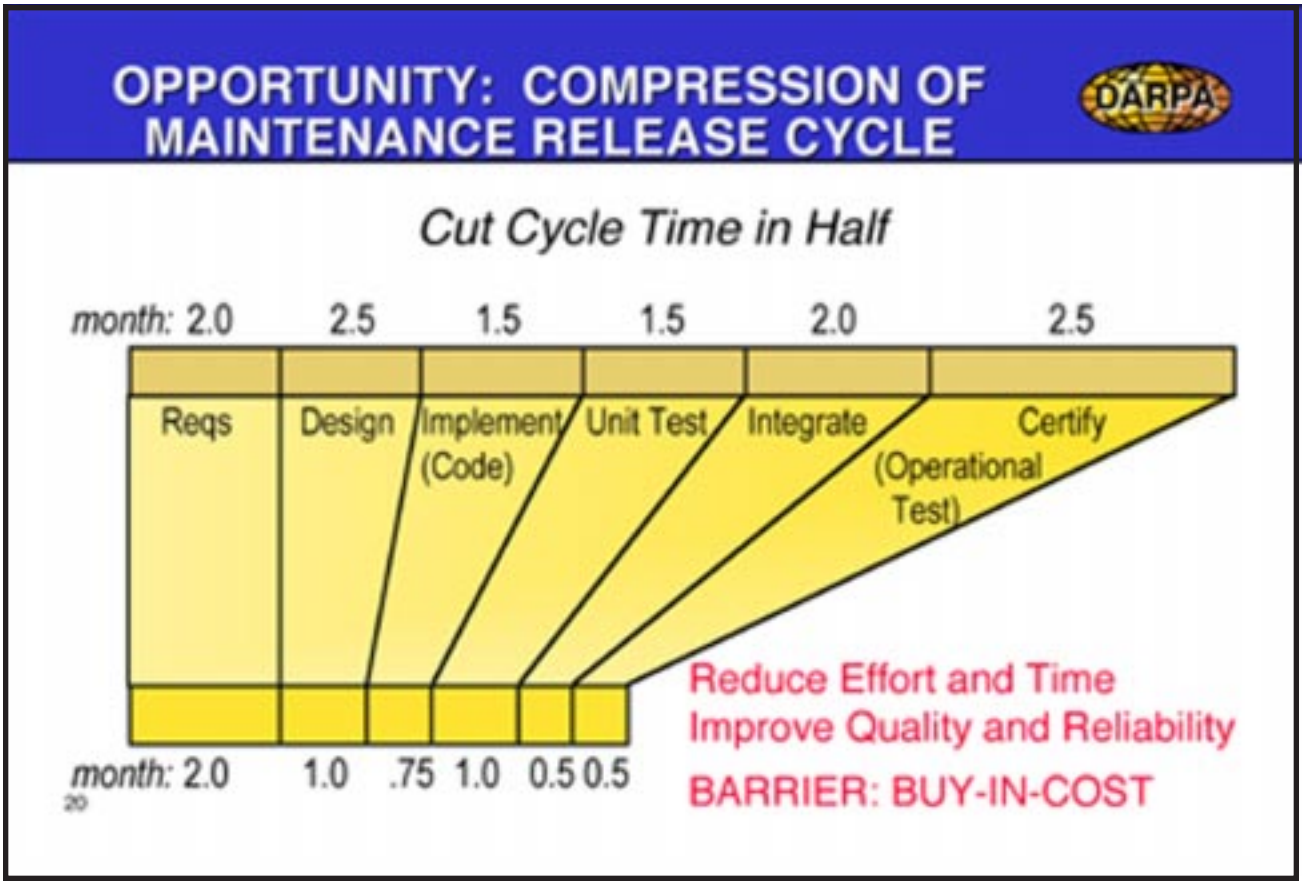
ITO's research program has three principal components studying

- The survivability of large-scale systems. Topics under study include wrapper generation, the coordination of intrusion detection and response, and artificial diversity.
- High Confidence Networks: Securing core network infrastructure services, such as the DNS.
- High Confidence Systems: Hardening node platforms.



Goals of the EDCS program include

- Making the cost of software modification and re-certification proportional to the size of the change.
- Software understanding and rationale capture technologies that assist developers and maintainers.
- Raising the level at which we think about systems.



One DoD contractor believes it can cut the maintenance release cycle time in half through the use of EDCS technologies. One of our aims is to reduce the buy in cost to the point where it's affordable for them to do so.

Incremental testing is expected to reduce testing time by 75%. In conjunction with run-time safety monitoring, we may be able to obtain an enhanced level of software safety.

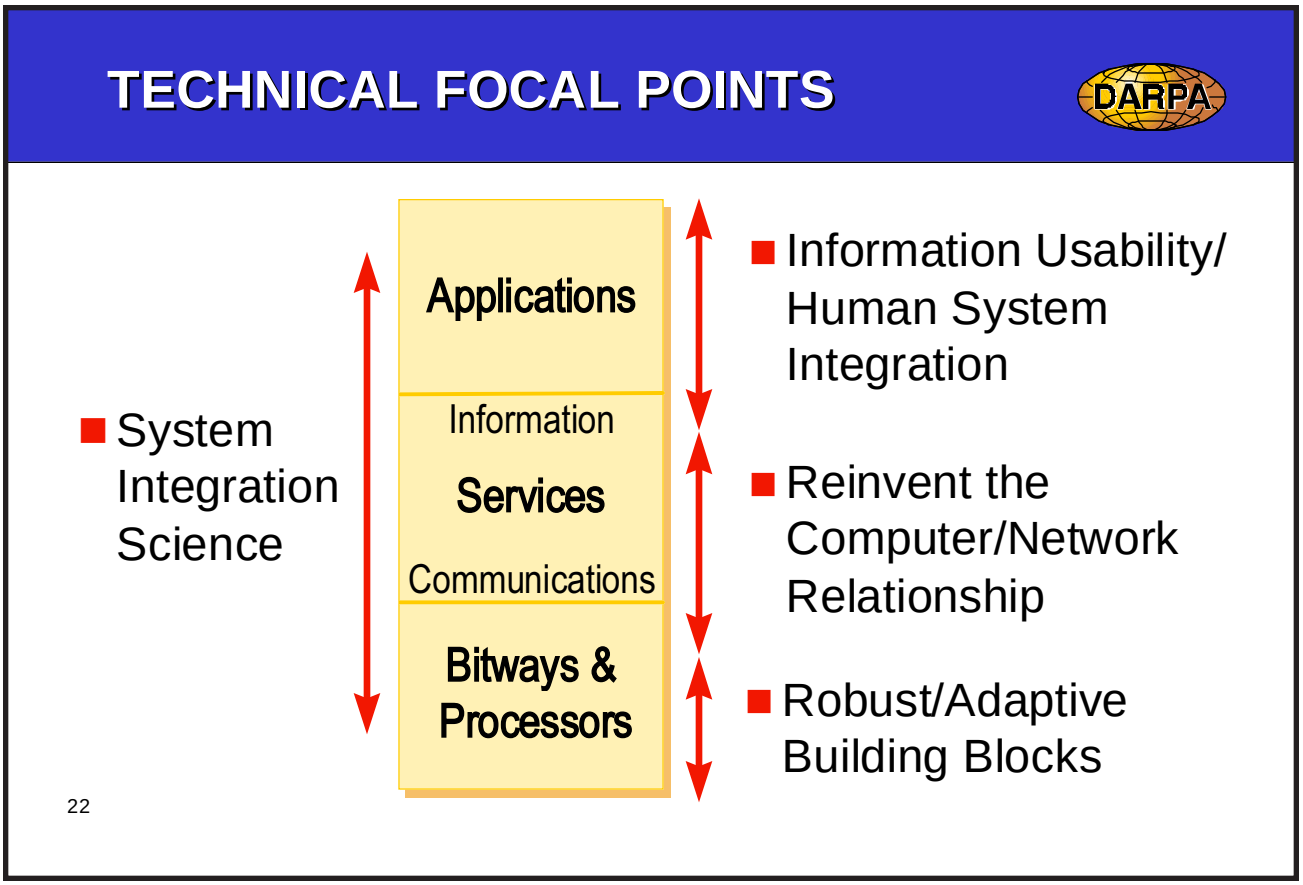
DEFENSE MISSION REQUIREMENTS

- Assured **Dynamic** Response
- **Robust** Performance and **Survivability**
- **Integrated** Human/Computer Interaction
- **Heterogeneous** Distributed Computing
- **Adaptable** Computing & Network Elements

21

And now for a word from/about our sponsor . . .

In the slide above, the words printed in **bold** identify areas in which DoD has unique requirements.



ITO addresses DoD's requirements by pioneering

- Dynamically configurable/programmable building blocks; and
- Sophisticated software technologies with which they are composed and manipulated.

FROM VISION . . . TO TRANSITION

"Seed" Projects: Identify Key Technologies
- Spawn the Next Great Ideas

"Leap Ahead" Projects: Move the Stake
- Moon Shots for Revolutionary Advances

"Acceleration" Projects: Eliminate the Barriers
- Experimental Testbeds and Technologies

"Application/Transition" Projects: Make It Real
- Move Technology Into the Field

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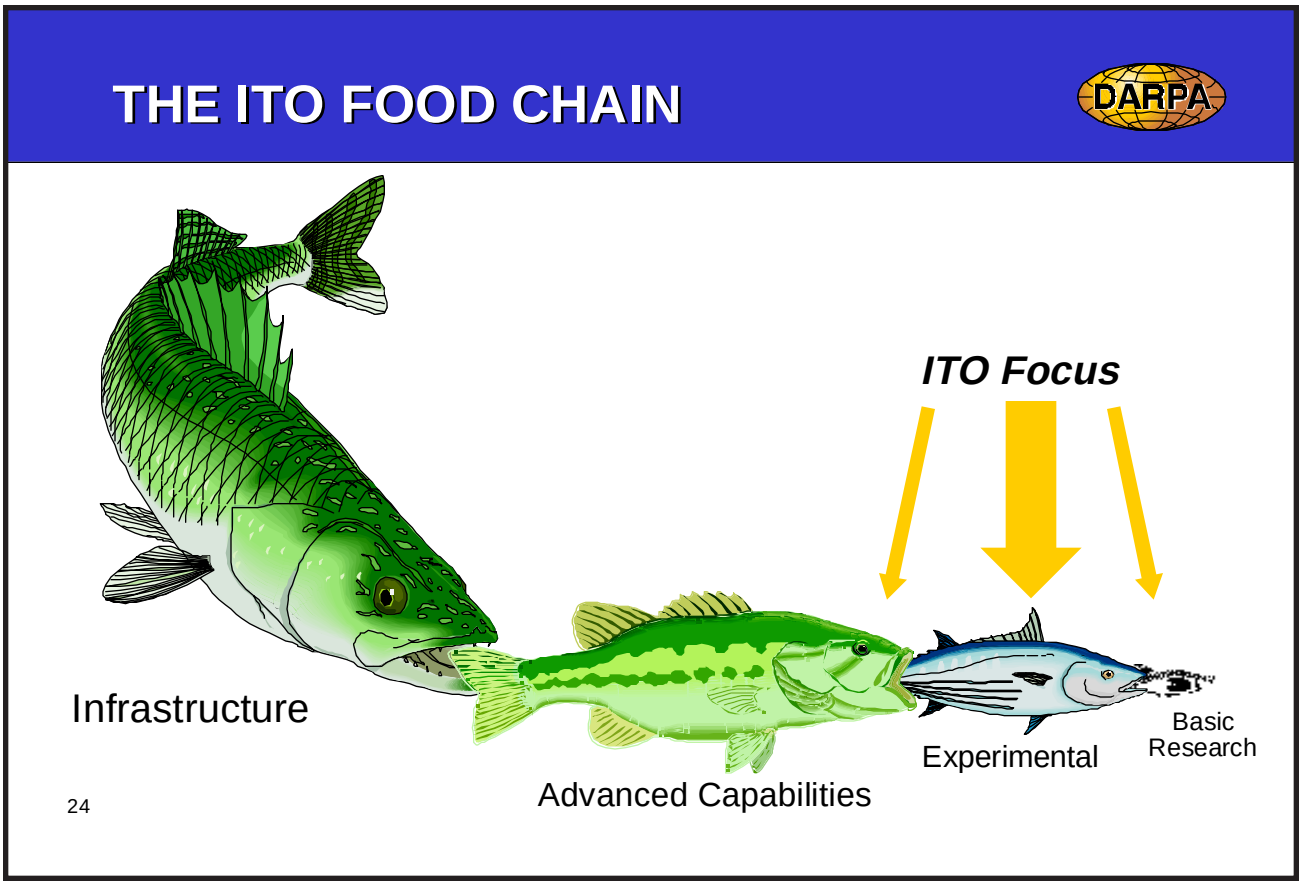
ITO's programs cover a wide swath of the technology development cycle. Historically, one of our key strengths has been the ability to guide technology investments through a series of stages.

Consider DoD's investment in packet switching:

- a "seed" stage of studies on packet switching (60)
- a "Leap Ahead" ARPANET stage (70s)
- "acceleration" through development and deployment of internetworking (80s) and ATM & WDM (90s)

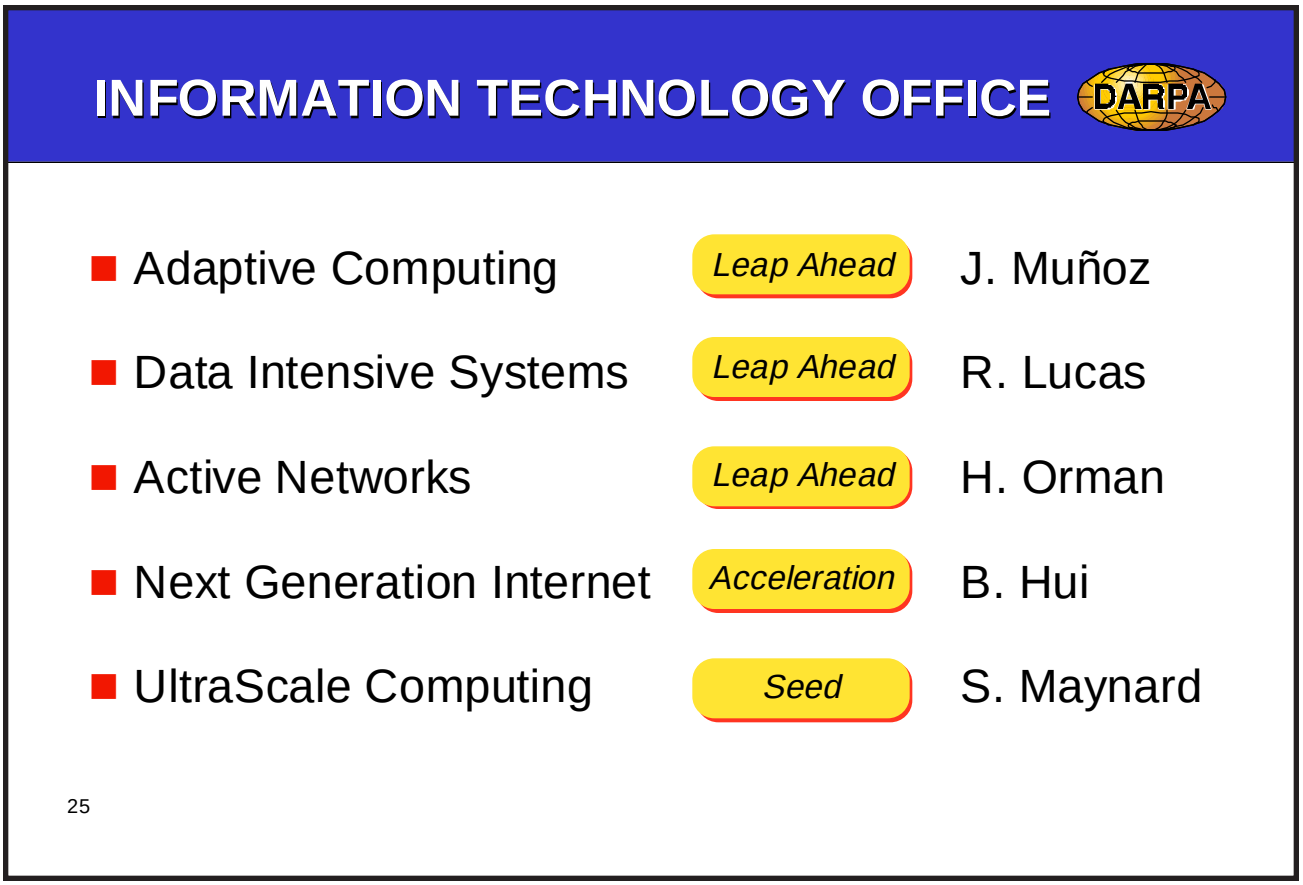
Today, we are set to continue that "acceleration" through NGI and take a "leap" beyond packet switching with the development of Active Networks.



The organization of our work into stages, each of which has well-defined objectives and/or ROI to the DoD, has allowed DARPA/ITO to sustain investment over extended periods.

However, it is the quality and creativity of our Program Managers that has allowed us to sustain technical leadership. The intellectual "churn" ITO achieves through the circulation of talented and highly motivated personnel has been crucial to our success.

It is our Program Managers, some of whom you are about to hear from, who will make everything I have just spoken about come to pass.



Here are some of the ITO programs you will hear more about during the next two sessions of this conference.

For information on these and other ITO programs, please consult our web pages, accessible via www.ito.darpa.mil.